This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

QE
146
.C4
C97

B 938,993

[illegible]
Reserve University
Cleveland, Ohio

Israel C. Russell

University of the State of New York

New York State Museum

Frederick J. H. Merrill *Director*

GEOLOGY OF RAND HILL AND VICINITY, CLINTON COUNTY

The area comprised in the Mooers atlas sheet

BY

H. P. CUSHING

Reprinted from the 19th annual report of the state geologist

ALBANY
UNIVERSITY OF THE STATE OF NEW YORK
1901

M91m-Je1-300

.H6
.C4
C97

1837
ARTES
VERITAS
SCIENTIA
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
SI QUAERIS PENINSULAM AMOENAM
CIRCUMSPICE

GEOLOGY OF RAND HILL AND VICINITY CLINTON CO.

Geography

The Mooers topographic sheet covers that part of Clinton county between longitude 73° 30′ and 73° 45′ and between latitude 44° 45′ and the Canadian line. It comprises a considerable part of Altona and Mooers, as well as portions of Beekmantown, Champlain, Chazy and Dannemora townships. The included area contains approximately 218 square miles. The larger portion of this area constitutes a part of the great plain which slopes from the northern foothills of the Adirondacks to the St Lawrence river. That part of this plain which lies in Clinton county slopes to the northeast, that in Franklin and St Lawrence counties to the northwest, away from a north and south axis of elevation along the west edge of Clinton county.

Along the eastern border of the sheet there is a rapid drop, step-fashion, from the level of this plain to that of the much lower plain of the Champlain valley. As the former slopes considerably, the latter but slightly, toward the north, the distinction between the two plains fades out in the northeastern corner of the sheet.

In Dannemora and Beekmantown the foothill belt of the Adirondacks rises above the level of the plain, a series of ridges and valleys in which the hilltops reach all sorts of altitudes and the ridges trend in various directions, and which sinks beneath, or is overlapped by the rocks of the high plain.

In a broad view then, the surface is a plain sloping from an altitude of 1600 feet in the southwest to only 200 feet in the northeast corner of the sheet, or about 70 feet to the mile. Going to the eastward from the southern limits of the map, the drop to the same level is much more abrupt. The main stream on the sheet, the Big Chazy river, which rises in Chazy lake not far beyond the limits of the sheet, follows in a general way

268214

the slope of the surface. Though it has a steep gradient, it has not occupied its present course sufficiently long to have channeled its valley very deeply, specially as the rocks of its bed are mostly very resistant, and the stream itself above Mooers Forks is of no great size. The sharp turn to the east at the forks is due to a glacial moraine across its course which crowds the North branch into the main stream and nearly does the same thing to the English river.

As is the case with all young streams, (that is, streams which have not been flowing in their present channels sufficiently long to have cut them down to grade, and which are therefore actively engaged in deepening them) the courses of the streams on the sheet consist of a series of slack water reaches interrupted by waterfalls and rapids, the latter marking the position of beds which specially resist erosion, followed down stream by those of less resistance, so that the slope at the junction of the two is accentuated by the more rapid cutting away of the later beds. The slack water reaches above are produced by the cutting away of the less resistant rocks above down to the level of the resistant bed at the brink of the fall. As the various layers of sandstone over which the streams flow do not vary excessively in resistance, these features are not as pronounced as they would be, were the variation greater and the different beds thicker. Instead of high falls and long reaches, the falls are frequent and of no great magnitude.

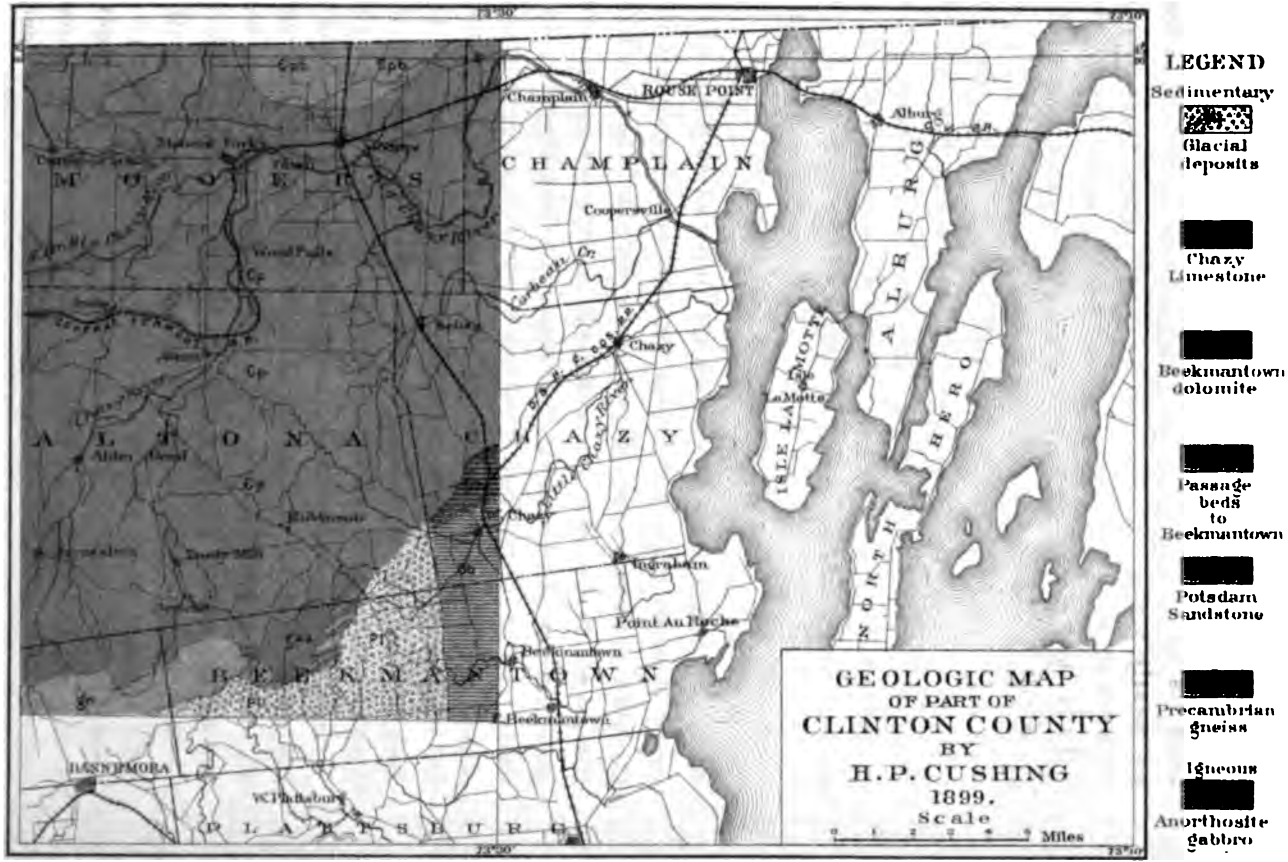
The irregularity of surface of the plain is due in large part to stream erosion, but also in considerable part to displacement. The drop from the high plain to the Champlain valley plain is also along a line of displacement. The surface has been much modified by glacial action, and is less diversified and less thoroughly drained than before the glacial period.

The larger part of the area of the sheet was originally densely forested with white pine on the sandy flats and with spruce and hard wood elsewhere. The pine was long since cut away, and the spruce and hard wood in large part lumbered. Some still remains which will likely go the way of the rest within the next

STATE MUSEUM

FREDERICK J. H. MERRILL
DIRECTOR AND STATE GEOLOGIST

19TH ANNUAL REPORT



JAS B. LYON
STATE PRINTER

few years. Fire has usually followed the ax, and old "burns" cover a considerable part of the district, often being almost impenetrable. Birch and poplar spring up to take the place of the more valuable woods.

The bare ledges of sandstone in Altona and elsewhere, known locally as "Flat rocks", are covered with a profusion of blueberry bushes, and the berries are picked in great quantity for shipment in the summer. There is comparatively little good agricultural land on the sheet, the greater part of the surface being sandy, marshy or of bare rock. From West Chazy southward, on the limestones, is the best farming land. Considerable farming is also done in the north of Mooers on the heavy moraine there.

Summary of geologic history

The oldest rocks within the area of the sheet, exposed on Rand hill and thence westward, are among the oldest rocks of which we have knowledge anywhere on the earth's surface. Similar rocks are at the surface throughout the Adirondack region, but they are so old and so changed from their original condition that it is an exceedingly difficult matter to decipher the history which they record. They are in part of unquestionable igneous origin, and have reached their present position by coming up from below in a molten condition and then slowly solidifying. In part they are believed to be old, water-deposited rocks, ancient sheets of sand, mud and calcareous mud laid down on the bottom of some large body of water, in all probability the sea. These are now so greatly changed from their original condition that the structures characteristic of rocks so formed have been almost or entirely destroyed and replaced by others which are not distinctive since they may be produced in igneous rocks as well. The inference as to their original condition is based for the most part on their composition. In third part they comprise rocks which have the thoroughly crystalline character and foliated structure of the rocks of the second group, but whose composition does not suggest that they are of sedimentary origin; they may be either changed sedimentary or igneous rocks, but are regarded somewhat doubtfully as being of igneous origin.[1]

None of the old water-deposited rocks occur within the limits of the sheet, the oldest rocks found being gneisses of uncertain origin, in Dannemora and Beekmantown. After their formation and when they were essentially in their present condition the mass of igneous rock now constituting the gabbro mass of Rand hill was intruded into them from below. At the time of this intrusion the rocks now at the surface were at a depth of at least 5 miles, that is they had at least that thickness of rocks above them, and the igneous rock solidified at that depth. At some time after solidification all the rocks were subjected to great compression, and the massive igneous rock was converted into a gneissoid rock. A long period of erosion followed, hence the region must have been above sea level at this time. The result of this slow but long-continued wearing away of the surface was to decrease the depth at which the present surface rocks lay buried. Another period of deformation followed and the rocks were fissured, sheared and probably faulted, the difference in the character of the deformation being due to the fact that the rocks were less deeply buried and hence under less load than during the previous deformation period.[2] The main set of fissures so produced had an east and west trend and a nearly or quite vertical inclination. During or closely following this period igneous rock again worked its way up from below, following these east and west fissures. Whether any of this molten rock ever reached the surface or not can not now be told, as no vestige of that old surface now remains. The old lava-filled channels of ascent however are still to be seen, and to such the term " dikes ", is applied. There are two sets of these, corresponding to at least two separate periods of intrusion. The lava of the first was fairly acid and gave rise to the red, syenite dikes which are quite numerous on Rand hill, while that of the second was very basic and the source of the black, diabase dikes so common throughout the region.

---

[1] Crystalline rocks in which there is a more or less parallel arrangement of the constituent minerals, due to which there is a tendency to split or cleave in one direction into more or less even slabs or layers, are said to have a foliated structure. The splitting is usually due to the presence and parallel arrangement of some cleavable mineral such as mica. The foliation is better and more even in schists than in gneisses.

[2] At a sufficiently great depth below the surface the pressure due to the weight of the rocks above is so great that the formation of cracks or cavities is impossible. The necessary depth varies with the kind of rock, but at 5 or 6 miles all fracturing is impossible, that is the formation of open fractures. Hence the character of the effects produced by deformation is an indication of the depth at the time of deformation.

Another long period of erosion followed, the region still continuing above sea level, and many hundreds of feet of rock were worn away from the surface. Then a slow depression of the district commenced and continued sufficiently long to submerge probably the entire Adirondack tract beneath the waves of the sea. The surface of the sinking land was much more even than it is at the present day, though it still had considerable relief. The stream valleys were well marked and separate by low, rounded hills or ridges. During the long continued erosion period the land must have suffered repeated uplifting in order to permit the removal of so great a thickness from the surface.

During the first part of the period of subsidence the sea was shallow over the land, and sheets of coarse sand, with much gravel, specially at the base, were laid down. Then, either because more rapid subsidence deepened the sea, or else because the land was so lowered and submerged that it was incapable of furnishing more detritus, the waters gradually cleared, and the various limestones, Calciferous, Chazy and Trenton, were laid down in the order named as calcareous muds on the still subsiding sea floor. During the earliest part of this period occasional sheets of sand were swept in by currents and alternate with the calcareous layers. During the deposition of the Trenton limestone currents washed in a certain amount of fine mud from time to time, from some land area probably to the northeast. This increased in amount, in consequence probably of shallowing and the nearer approach of some land area, and the calcareous muds of the Cumberland head rocks and the black muds of the Utica slate were laid down on top of the limestones.

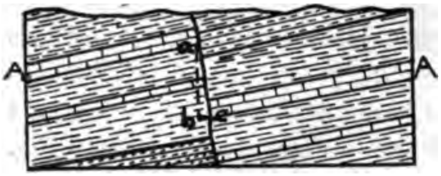
Whether the Lorraine shales, which overlie the Utica slate in the Mohawk valley, were ever deposited in the Champlain valley is a question which can not at present be answered. If so, no trace of them has yet been found.

Be that as it may, the downward movement which had been in progress so long, ceased after the laying down of the Utica or else of the Lorraine shales, and was succeeded by a movement in the contrary direction which carried the whole district above sea level, where it has, for the most part, remained ever since.

Either this upward movement was accompanied by, and likely caused, by deformation; or else deformation ensued not long after the uplift. The effect was greatest in Vermont, and the result there was the uplifting of the Green mountain range the rocks there being considerably folded as well as faulted. In New York only a slight amount of folding was produced, but extensive faulting took place.[1] Some of these faults are easily detected and, moreover, are of considerable magnitude. The Tracy brook fault, for example, has a maximum throw of close to 2000 feet. It is not meant to imply that there was ever that difference in level at the surface on the opposite sides of the fault plane. Such movements are in general so slow that the more rapid erosion on the rising side of the fault may lower its level very materially while the movement is still in progress. There is evidence also of repeated movement, along some of the faults at least, down to comparatively recent times, if indeed such movement is not still continuing.

---

[1] A fault is produced by a sliding movement of the rocks on opposite sides of a fissure, with the result that the same rock stratum is higher on one side than on the other, as illustrated in the accompanying diagram. The stratum AA has been dropped on the right side of the fault relative to its position on the left side. The distance *ac*, measured along the fault plane, is called its *displacement*, the vertical distance *ab*, that separates the two ends of the stratum, is called the *throw*, and the horizontal distance *bc* is the *heave* of the fault.



During or shortly after this deformation period occurred the last outbreak of igneous activity in the vicinity, molten rock again rising from below through the set of east and west fissures. If any of this material ever reached the surface, all trace of it has been worn away, and we see at the present time only the dikes, as the old fissures are called through which the rock worked its way upward and in which it cooled as the activity ceased, filling them solidly from side to side. The Adirondack region was not a center of the igneous activity of this period but on the border, the dikes of this age occurring along the shores of Lake Champlain but not extending back from it for any considerable distance. No dikes of this period have been discovered within the limits of the Mooers sheet, though they are found along the lake shore in the territory covered by the Plattsburg sheet, next southeast. As in the preceding time of igneous rock formation, there were at least two separate periods of activity, the rock of the one being a light colored, acid rock, and of the other a black, basic rock. There are constant differences between these rocks and the preceding diabase and syenite, such that where both occur they may be distinguished. The acid rock followed, instead of preceding the basic, as in the earlier period. With this outburst igneous activity in the region terminated.

There is a possibility that during late Upper Silurian or early Devonian time the region was again depressed below sea level for a short time, at least that the Champlain valley was. The valley came into being as a topographic feature with the faulting of the previous deformation period. There is evidence that the St Lawrence valley at Montreal was below sea level at the time specified, and it is simply inferred that the Champlain valley may have been also affected. If so, every vestige of the deposit laid down on that sea floor has since been eroded away. With the exception of this possible short time of depression the district was a land area throughout the entire vast interval from the close of Lower Silurian time to the comparatively recent departure of the Pleistocene ice sheet. This interval certainly represents at least three fourths of the entire elapsed time since the beginning of deposition of the Potsdam sandstone, quite likely considerably more. Its duration was certainly several, quite likely many million years. Few parts of the earth's surface have been continuously above sea level for so long an interval.

During this enormous length of time this surface has been subjected to continuous wear. Its history is to be read in the removal, not in the deposition of rocks. From this standpoint a sharp contrast is to be noted between the Champlain valley on the one hand and the Adirondack highlands on the other. The Trenton limestone and the Utica slate are still found here and there in the valley. In such places no great amount of erosion can have taken place. Compared with the other rocks of the region these are the least resistant of all, and their presence forces the conclusion that the Champlain valley was early outlined as a valley and must have remained pretty persistently at a comparatively low altitude. The Paleozoic rocks have suffered more or less considerable erosion on the upthrown side of fault blocks, but the loss has been very small from the downthrow blocks.

On the Adirondack highlands, on the other hand, the entire cover of Paleozoic rocks has been worn away from the surface, except for an occasional insignificant patch on the outskirts. This implies the removal of not less than 2000 feet thickness of such rocks from the whole surface, and more likely double that amount. An unknown amount, probably not excessive, has also been worn away from the surface of the underlying rocks.

It must not be supposed that this necessarily implies that the district ever had an altitude much greater than the present. It seems to have been an uneasy region with frequent small movements of uplift. If long periods of quiescence had intervened, they would have assuredly left their mark in the shape of well defined old base levels of erosion, but such are not to be discovered. Comparatively recent uplift is, furthermore, indicated by the plainly marked character of the north and south axis of uplift along the west edge of Clinton county, and thence southward, as a topographic feature. The faults have served as lines along which frequent displacement has taken place.

In comparatively recent times, so recent that the deposits formed have suffered but little erosion, the region was covered by the Labrador ice sheet. Shortly before the oncoming of the ice it stood at a considerably higher level than the present. The retreat of the ice left the surface mantled with glacial deposits, laid down to greatest depth in the old valleys, so that the surface was more even than before. During the long time that the ice sheet covered the region a slow subsidence was going on, with the result that the retreat of the ice found the altitude some 600 feet below the present, a depression of sufficient amount to permit an arm of the sea to extend up the St Lawrence and Champlain valleys on the disappearance of the ice barrier. The sands and clays deposited there are found at present running up to the 400 foot line and possibly higher. They contain shells of the mollusks which lived in the cold waters and which are of the same species as living forms, some of which are yet found in the Gulf of St Lawrence, while others are confined to colder, arctic waters.

Besides these marine levels there are standing water levels at higher elevations in the valleys opening into the Champlain valley; and these waters must have been fresh, have preceded the salt water incursion, and have been held up at those levels by an ice tongue which lingered in the Champlain valley after the ice had completely melted away from the adjoining highlands, because of its original much greater thickness there.

Since the departure of the ice sheet the region has been slowly uplifted to its present hight. The marine shore lines along the lake are no longer level but rise slowly toward the north, showing that they have been tilted since they were formed, and hence that the uplift was greatest in that direction. The elapsed time since the ice sheet disappeared is so slight that erosion has modified the surface only in slight degree. The deposits formed by the glacier and in the bodies of standing water which followed are substantially as they were left by them.

Dannemora formation

Of the three classes of pre-Cambrian rocks which have been mentioned, the distinctly sedimentary rocks appear nowhere within the limits of the sheet, nor are any known within the immediately surrounding territory. The prevailing rocks over a large part of the northern Adirondack foothill region are gneisses of doubtful, though for the most part probably of igneous origin, which are distinctly older than the unmistakably igneous rocks. Such rocks are at the surface in the territory comprised in the southwestern part of the sheet. The term, Dannemora formation, is suggested as a convenient one to apply to these widespread rocks on the north, in our present state of ignorance concerning their age and relationships, as they are well exposed all over the mass of Dannemora mountain as well as throughout Dannemora township. The problem of their age, and their relationship to the undoubted sedimentary rocks, is by far the most important unsolved stratigraphic question in the district. Most unfortunately there is practically no opportunity afforded for its settlement, since in the region where the Dannemora formation prevails the other rocks are wellnigh absent, and no contracts where these relations might be shown and studied, are exposed. Nearly all the exposures of the sedimentary rocks in Clinton and Franklin counties are surrounded by the later eruptive rocks instead of the Dannemora formation. Whether therefore the Dannemora rocks are older, younger, or of the same age as the sedimentary (Grenville) rocks does not appear, and the evidence must be forthcoming elsewhere, probably from the western Adirondacks.[1]

---

[1] Every geologist who has visited the Adirondack region has remarked on the great similarity, if it be not identity, of the pre-Cambrian rocks to the Canadian rocks to the northward. This is specially true of the igneous rocks and those of sedimentary origin (long ago named the Grenville series by Logan). There is also there a supposedly older series of gneisses known as the Ottawa gneiss. The term, Ottawa gneiss, is not used in this report simply because it is not yet determined whether the Dannemora gneiss is the representative of the Ottawa gneiss in the Adirondacks, or whether it represents rocks which are classed with the Grenville series in Canada, or whether it represents neither. The term, Grenville, *is* used for the sedimentary series because the similarity between these rocks in the two districts has been noted by every observer who has gone into the field, and it is exceedingly probable that they were deposited in the same basin. Smyth has suggested the name, Oswegatchie series, for these rocks in the western Adirondacks, on the ground that their similarity with the Canadian rocks does not neces-

The rocks of the Dannemora formation are quite varied and yet quite uniform. Nearly every outcrop shows two or more varieties of gneiss interbanded with one another. The rocks also differ much in coarseness or fineness of grain from place to place. Yet there are practically only four varieties of gneiss in the district, which however grade into one another through intermediate varieties.

The two most abundant kinds of gneiss in the vicinity are a finely granular red gneiss which has the composition of a granite, that is, made up of quartz and microperthitic feldspar with additional small amounts of either hornblende or biotite or (more rarely) augite, and magnetite; and a black, more gneissoid rock with the essential make-up of a diorite, that is, composed of hornblende and a feldspar ranging from oligoclase to labradorite in composition, with magnetite and either biotite or augite in addition. With these are occasional streaks of a gray gneiss composed of biotite, hornblende and an acid plagioclase feldspar, quartz being mostly lacking; and gray to red, evenly granular rocks of quartz, orthoclase feldspar and abundant pyroxene which are often called pyroxene granulites. All these gneisses are cut by a later coarse, red granite or granitoid gneiss, which occurs either in small masses cutting across the foliation of the gneiss, or else more intricately cutting it in thin films and sheets which are in general parallel to its foliation.

---

sarily show equivalence in time. This term has priority for the Adirondack rocks if a new name is to be used. But no one can now show whether the rocks of the two areas are, or are not, equivalent, nor is any one likely to be able to do so in the near future. No one has any idea of the thickness of either series, nor even how many beds of limestone there are. There may be just as great a difference between the eastern and western Adirondack rocks in age as between either and the Canadian. There must be a great difference in age between the top and bottom of the series. It seems therefore to the writer more logical to use a name which brings out a universally observed relationship, rather than to inject into an already overburdened literature a new term, based on what is at present a wholly gratuitous supposition. In these old rocks in which fossils are lacking, it is impossible to apply the same fine discriminations as in the fossiliferous rocks, and it would seem to be time enough to apply a new name when non-equivalenee is shown to be something more than a mere possibility.

This complex of gneiss and granite makes up the mass of Dannemora mountain and forms the hills in Dannemora and Beekmantown in the southwest corner of the Mooers sheet.

As has been stated in previous reports, if there is any formation in the northern Adirondack region which is the equivalent of the Ottawa gneiss of Canada, or which may be of Archaean age in the restricted sense in which that term is now employed by the United States geological survey, it is this Dannemora formation. Unfortunately in the district in Clinton and Franklin counties in which it prevails, the Grenville series is practically absent, and a rather careful survey of the area has failed to disclose any exposures which throw any light on the question. The problem is much complicated by the intimate association of very similar gneisses with the undoubted Grenville rocks in the western Adirondacks, where, if anywhere, there is a prospect of settling this question.

On Rand hill, specially at its eastern edge, is considerable gneiss which is cut through and through by the gabbro, with unmistakable irruptive contacts, showing that the gneiss is the older rock.[1] The gneiss that appears on the west side of the hill is mainly of the black dioritic variety, though there is much of the red gneiss also. It seems totally unaffected by the gabbro, and there is thought to be a fault between, though the evidence of this is not decisive. On the east the gneiss is best shown along the cliff face and along Mead brook. Here it is all cut up by the gabbro and differs quite materially in character from that on the west. Nowhere else in the Adirondack region has the writer seen such contacts, nor has he met elsewhere a gneiss precisely similar to this.

It is for the most part a well foliated, black and red or black and gray gneiss, quite like some intermediate varieties of the ordinary gneiss. But often, specially near the gabbro contact, it is hard and flinty and breaks with a conchoidal fracture. In composition it is either a quartz-orthoclase-hornblende, or quartz-orthoclase-augite rock.

---

[1] Rand hill, as here used, applies to the whole area on which the gabbro outcrops, the low north end as well as the summit; locally it is usually restricted to the latter.

Under the microscope the same indefinite, granular structure is shown which the ordinary gneiss possesses, except that near the gabbro there are also corrosion zone (reaction rim) structures quite like those in the gabbro itself. Along Mead brook are a series of most excellent exposures of rapidly alternating gneiss and gabbro, the latter cutting across the foliation of and sending dikes into the former. This gneiss is essentially made up of orthoclase, hornblende and quartz, with accessory zircon, apatite, pyrite, magnetite, garnet and biotite. The magnetite is nearly always surrounded by hornblende. The hornblende is patchy, very irregularly bounded, and full of small biotite shreds which seem secondary; commonly also the magnetite and hornblende are separated by a narrow zone of biotite, consisting of closely packed, very minute shreds. Considerable garnet has formed in places at the contact between hornblende and feldspar, accompanied by small grains of secondary quartz. Precisely similar corrosion zones are found in the gabbro near the contact. The garnet zones are found all through the gabbro, but the biotite zones have not been noted except near the contact, though they may occur. The writer is disposed to explain the facts by the assumption that the gneisses on the east and the west side of the hill are the same, and that the differences noted on the east side are due to contact metamorphism, with the production of a narrow zone of mixed composition between the two rocks, due to incorporation in the gabbro of material from the gneiss.

The augite gneiss from the same locality is an even more flinty rock, and in it garnet has been largely developed at the contacts between both magnetite and augite, and feldspar. This would imply that the feldspar is plagioclase, though it is largely untwinned. In the ordinary Dannemora gneiss garnet is a rare mineral, though abundant in the Grenville gneisses. No similar rock has been observed on the west side of the hill, and the amount of change produced by the intrusion is a matter of uncertainty.

Gabbro intrusions

There are two main varieties of gabbroic rocks exposed in the district: the one the coarse grained, blue-black rock, weathering white, which forms the main mass of Rand hill; the other a fine-grained, black rock, occurring only in dikes or in small bosses, which cuts and is therefore later than the other—which is, in fact, the youngest of the older Adirondack eruptives. It is one of the most widespread rocks in the whole Adirondacks, though the total bulk is not great. It is usually gneissoid, though often unchanged cores remain, and these have an ophitic structure, that is the feldspars are in well formed, lath-shaped crystals, giving a characteristic appearance to the rock. It belongs to the gabbro variety known as hyperite, and has been frequently described in detail, of late, by the different workers in the region, so that no extended description is called for here. The gneissoid phase is readily distinguished from the older, hornblende gneisses by the usual dike-like form, finer grain, poorer foliation and general more firm and resistant character.

The first variety is merely a phase of an igneous rock which has a wide extent in Essex and Franklin counties and whose nearest outcrops are on Halleck hill north of Keeseville. The Rand hill rock is peculiar and unlike any heretofore described from the Adirondack region. While the ordinary Adirondack rock is related to the gabbros, it is of a special and peculiar type to which the name, anorthosite, has been applied. The Rand hill rock is of an intermediate type which may be distinguished by calling it anorthosite-gabbro.

Anorthosite-gabbro

Anorthosite is a deep-seated igneous rock composed essentially of labradorite (or some allied feldspar) with accessory augite, hypersthene and titaniferous magnetite (or ilmenite), the total amount of all these being but slight. Gabbro is a similar rock of augite (or hypersthene) and labradorite in an approximation to equal quantity. Anorthosite-gabbro, while predominantly feldspathic, has the other minerals in sufficient quantity to make it necessary that they be considered essential constituents of the rock rather than mere accessories.

The Adirondack anorthosites were originally very coarse grained rocks, the individual crystals of labradorite often attaining a length of three inches or more. The deformation which they suffered while deeply buried, more or less broke up these large crystals into a mass of granular fragments, with the result that the rocks as now exposed consist partly of the unbroken portions of the original crystals and partly of the granular material, sometimes the one and sometimes the other predominating, though usually the latter. They were also somewhat foliated, specially at the borders of the mass, where there is a frequent passage into a well foliated gneiss in which little or no trace of the original structure remains.

The Rand hill rock is much more thoroughly granulated than the usual anorthosite and was, most probably, originally a finer grained rock. In the southerly exposures the granulation is practically complete, and no labradorite *augen* (a convenient term for the uncrushed parts of crystals) remain. It is only in the northerly exposures that such are found, and even there the bulk of the rock is granulated. Many augen however remain, running up to an inch in size, though seldom exceeding that figure. As in general the border portions of these intrusions are the most crushed, it is not probable that we are here dealing with the limit of the mass in this direction, it in all likelihood continuing to the northward under cover of the Potsdam sandstone.

Since the Rand hill rock contains a larger amount of minerals other than feldspar, than does the usual anorthosite, it was more definitely foliated by deformation, and much of the rock exposed is thoroughly gneissoid. As a whole however it strongly resembles some of the border phases of the larger intrusions.

The most important difference between this rock and anorthosite consists in the constant presence in considerable amount of quartz; so that strictly it should be called a quartz-anorthosite gabbro. The rock is of somewhat unusual type, has not been heretofore described from the region, and is therefore deserving of minute description. Unfortunately it has not been investigated chemically.

Mineral content

The primary minerals (those formed by the original cooling of the rock) which have been noted in the Rand hill gabbro are as follows, in relative order of abundance: plagioclase feldspar (usually labradorite), augite, quartz, hornblende, hypersthene, apatite, ilmenite (or titaniferous magnetite), zircon, pyrite, pyrrhotite and titanite. Secondary minerals are garnet, hornblende, biotite and quartz. There are a number of other minerals present which have resulted from the excessive alteration or decomposition of the foregoing, but they are the usual ones and do not need farther mention. The order of crystallization was the usual one, first the zircon and apatite, followed by the iron ores, then the hypersthene, augite and hornblende, whose relative order is not apparent, next the feldspar and last of all the quartz. The periods of formation of the dark silicates and of the feldspar largely overlap.

The feldspar is in all respects like that of the anorthosites. It is full of inclusions of uncertain nature, mostly of short, stout, opaque rods. It is usually a well twinned plagioclase, albite twinning being well nigh universal, that after the pericline law often combined with it, but Carlsbad twinning being very exceptional. Sections cut perpendicularly to the twinning plane show maximum extinctions of from 20° to 24° in all the slides. This makes it reasonably certain that no feldspar more basic than labradorite is present, though not precluding the possibility of a more acid one being at hand in slight amount. Five cleavage pieces (parallel to the M cleavage) from different augen give extinctions of from —15° to —17° from the edge of the P cleavage, with an average of —16°, which is precisely the angle of typical labradorite, $Ab^1 An^1$.

Of the pyroxenes hypersthene is relatively rare, a light green, non-pleochroic augite being the usual mineral. This is identical with the usual augite of the anorthosites and has been often described.

While there is unquestionably some primary hornblende in this rock, much of this mineral is secondary after augite, and most of the rock is not sufficiently fresh to permit a good judgment as to the relative proportions of the two. When the respective amounts of hornblende and augite are compared, much variation is found, and some of the rock would be more properly described as a diorite, rather than a gabbro. In general the augite preponderates, and the close relationship between these rocks and the anorthosites is so evident that the general application of the term, gabbro, to the whole is perfectly justifiable.

The ilmenite (or titaniferous magnetite) and the zircon are quite as in the anorthosite. Occasional crystals of the latter are of sufficient size to be visible with a hand lens.

Pyrite and pyrrhotite are not as abundant as in many parts of the anorthosite, but both are sparingly present.

The great abundance of apatite in much of the rock is one of its unusual features. In addition to the usual minute, slender crystals is much coarser apatite in irregular grains, often concentrated in little streaks which run clear across a slide. It is very irregularly distributed, but at a rough estimate there is from 3% to 5% in the rock as a whole, and several of the slides show from 5% to 10%.

As has been stated, this rock underwent deformation while deeply buried. The individual crystals were strained, bent, broken and more or less completely granulated, with considerable recrystallization accompanying the process. That much of the granular feldspar has been recrystallized is indicated by the fact that much of it does not contain the minute inclusions which are so characteristic a feature of the original feldspar. In part also the granular feldspar is untwinned, and such individuals usually show irregular, patchy intergrowths of two different feldspars. This has not been carefully investigated, but such intergrowths are also found in some undoubted labradorites, and Becke's method indicates little or no difference in refractive power between the two feldspars.

The main difference in mineralogic make-up of the rock resulting from deformation is the production of abundant garnet. This is usually a dark red garnet (probably a lime-alumina-iron garnet) which occurs either as well formed crystals or as rims around the magnetite (ilmenite). It occurs between labradorite and magnetite, less often between augite or hornblende and labradorite, and never away from the feldspar. The material of which it is composed has been derived from the adjacent minerals, particle by particle, the garnet forming at their expense. As it is a more basic mineral than the labradorite, an excess of silica is left, which has crystallized out as quartz, partly inclosed in and partly bordering the garnet. What has become of the soda of the feldspar is an interesting question. It would seem that albite should have formed, but it has not been detected.

It is not easy to account for the fact that garnet has not been produced between magnetite and feldspar in all cases, but there are quite numerous instances of magnetite wholly surrounded by feldspars, or partly inclosed by them, in which there is no trace of garnet formation. Evidently some accessory to the process was present in the one case and absent in the other. It does not seem to have been water, since around some such magnetites the feldspar is thoroughly granulated and has apparently been largely recrystallized, implying the presence of water. The development may have been confined to the cleavage planes, and unquestionably is mainly in them.

In those parts of the rock in which garnet is scarce or lacking the magnetite is always completely inclosed by pyroxene and hornblende. To a certain extent such hornblende seems to have resulted from interaction of the magnetite and pyroxene.

Between hornblende, or pyroxene, and feldspar garnet is by no means so frequent as in the other association. It is in the more gneissoid varieties of the rock that it is found so associated most abundantly, here being well crystallized and strung out with the dark silicates along the cleavage planes. Here unquestionably much recrystallization has taken place, consequent on the deep-seated deformation, and the garnet formation is to be ascribed to this period. In the case of the corrosion zones around magnetite there may be some question whether the garnet developed at this time or earlier.

Quartz occurs in the rock associated with garnet, as already noted. But in addition there is much coarser, granular quartz along with the granulated feldspar. None could be found which could be definitely determined to be primary, most, if not all, of it having recrystallized during deformation. On the other hand, it is quite certain that the recrystallization has been nearly in situ, and that in the original rock an equally large amount of quartz was present. Some few large individuals found with large, uncrushed labradorites would seem in all probability primary. A rough estimate of the amount present in the rock would give a range from none to 15% with an average of at least 10%.

A farther indication of the considerable amount of recrystallization which the rock has experienced, is furnished by the occasional presence of quartz inclusions in feldspar and even in hornblende and augite, quite after the fashion of the inclusions in many of the gneisses.

Gabbroic rocks containing quartz have been described from several localities in many parts of the world; hence this occurrence is by no means unique. Yet it is exceptional and important. Notwithstanding the amount of quartz, it is by no means certain that the rock is more acid than the ordinary anorthosite. If from 3% to 5% of alumina was replaced by iron in the ordinary anorthosite magma, an excess of silica which would crystallize out as quartz would result. That this anorthosite-gabbro was derived from the same parent molten mass as produced the anorthosite, is beyond question.

The writer has previously called attention to the great similarity between the eruptive rocks of the Adirondacks and those of the Ekersund-Soggendal district in Norway, recently exhaustively described by Kolderup.[1] This writer describes a quartz-norite as occurring in considerable amount there; and the Rand hill rock furnishes still another illustration of the close parallelism of the two series.

---

[1] Kolderup, C. F. Bergens museums Aarbog. 1896. Die labradorfelse des westlichen Norwegens.

Cushing, H. P. Bul. geol. soc. Amer. 10:190.

An analysis of the anorthosite gabbro from Carne's quarry has been made by Prof. E. W. Morley to whom the writer wishes to express his great indebtedness. This analysis follows together with one of an Adirondack anorthosite and one of an Adirondack gabbro for comparison.

	1	2	3	4
$Si\,O_2$	47.42	51.62	54.62	.8603
$Al^2\,O_2$	17.34	24.25	26.5	.2397
$Fe_2\,O_3$	4.91	1.65	.76	.0103
FeO	10.22	5.3	.56	.0736
MgO	5.21	1.21	.74	.0302
CaO	8.09	9.97	9.88	.178
$Na_2\,O$	3.48	3.49	4.5	.0563
$K_2\,O$	1.89	1.27	1.23	.0135
$H_2\,O$	1.13	.72	.91	
TiO_2	3.6	undet.		
$P_2\,O_5$	.06	"		
Cl	.21	"		
MnO	.06	.1		
BaO	.04	undet.		
Total	100.06	99.78	99.70	
O=Cl	.05	Sp. gr. 2.8		
	100.01			

1 Analysis by E. W. Morley of the least metamorphosed hyperite gabbro that I have met in the Adirondacks, Hopkinton, St Lawrence co.

2 Quartz-anorthosite-gabbro, Carne's quarry, Rand hill, Altona township; analysis by E. W. Morley.

3 Anorthosite, analysis by A. R. Leeds, 13th annual report New York state museum, 1876.

4 Molecular ratios of analysis 2.

From the molecular ratios a rough calculation of the mineral composition of the anorthosite gabbro is readily made, the alkalies and a part of the lime being assumed to go into the feldspar, the residue of alumina and lime along with the iron and magnesia forming garnet, augite and hornblende. The result is as follows.

	%		%
Magnetite	2.4	Albite	29.7
Garnet	11.75	Orthoclase	7.5
Augite	11.0	Quartz	5.0
Anorthite	32.0		

This calculation agrees well with the evidence of the thin section as to the composition of the rock except that the latter would indicate a somewhat larger percentage of free quartz. But even 5% of quartz in a rock of this basicity is noteworthy, and some of the rock of the hill is considerably richer in quartz than that analyzed.

A comparison of the three analyses brings out clearly the close relationship of the rock to ordinary anorthosite on the one hand, and its intermediate position between that and gabbro on the other. But as in all gabbroic rocks there is much variation from place to place and unquestionably samples from different portions of the hill exposures would be found to vary widely. It is not thought that any is more basic than that analyzed, but likely much is somewhat more acid. While much of the Rand hill rock is very rich in apatite it is barely present in the rock analyzed.

Augite-syenite

On the east edge of Rand hill, near the top of the cliff, is a small area of a greenish gray, fine grained, rather gneissoid rock in which recently a quarry has been opened. This is classed with rocks quite widespread in the Adirondack region and recently described, though a small degree of doubt remains as to the correctness of the reference.[1] This rock is thoroughly granulated and gneissoid, with much recrystallization, yet, except for its finer grain, it has precisely the same appearance and mineral content as the ordinary augite-syenite as it appears at Loon lake or Tupper lake. Its minerals are hornblende, augite, bronzite, feldspars and quartz, with accessory magnetite, apatite and zircon, and garnet also in the outer parts of the mass. The feldspar is mostly anorthoclase, some showing plainly irregular intergrowths of two feldspars, probably orthoclase and albite. Quite a little oligoclase is present in addition. Quartz constitutes some 15% of the rock.

---

[1] Cushing, H. P. Bul. geol. soc. Amer. 10:177-93.

The outcrops of this rock are not extensive, and it clearly is a mass of no great size, extending only a few rods in any direction. On the east, down the hill, the rock appears to be grading into the ordinary gneiss, but no further exposures appear in that direction. In all other directions anorthosite-gabbro or else gneiss is reached at no great distance, but there are absolutely no contacts showing anywhere, so that the field relations of this apparent syenite are left in entire uncertainty. So far as the age of the augite-syenite is known, it is younger than the anorthosite, but that need not necessarily imply that it is younger than this anorthosite-gabbro. This occurrence may be a dike, though that is unlikely, as its extension could not anywhere be found; it may be a small intrusive mass, though it is exceptionally small for a mass of such origin. In the utter absence of field evidence the reference is made simply on the character of the rock.

Later igneous rocks

The much later age of these rocks is inferred from the fact that they are wholly unmetamorphosed, though they have suffered deformation. It is thought that this deformation would have caused metamorphism, had the rocks been buried deeply enough. The inclosing rocks are older and were metamorphosed before these later rocks found their way through them. When metamorphosed, they were deeply buried in the zone of flow, and are now exposed at the surface because all the overlying rock has been eroded away. But the later rocks exposed at the surface have never been in that zone. Much less rock had to be worn away to bring the present exposures to the surface, and hence a long erosion period between the time of formation of the inclosing rocks and of these later ones is argued. It is thought that the amount of material removed during this time will not fall short of the entire amount which has since been removed, but, even if this be an overestimate, the intervening period must have been long.

As has been already stated, these rocks are found at the present time only in dikes. We see the channels through which the material ascended, but can not tell whether any reached the land surface of that time, nor do we anywhere get a glimpse of the reservoirs which supplied the material, since erosion has not yet cut deeply enough to disclose them. The comparatively small area now occupied by these dikes thus gives little idea of the possible importance of this eruptive period. It seems however improbable that great surface flows should have taken place, else we should surely find remnants of them in protected places. It seems more likely that the forces of eruption were spent in forming intrusive masses from which the dikes radiated upward, dying out above. The dikes plainly owe their existence to the same causes which were responsible for the earlier, great intrusions, and mark the last paroxysm of igneous activity from that source.

The two distinct dike rocks of this period have been already noted. On Rand hill the two are more nearly of equal importance and abundance than in any other spot in the entire Adirondack region, and dikes of both sorts are very numerous. 19 of the red, syenite dikes have been found on the hill, of which seven were noted in a previous report.[1] The black, diabase dikes are even more numerous, but impossible to enumerate, since they are frequently found combined into a great dike plexus of many branches. The display of dikes is the most impressive known in the Adirondacks. It must either signify an intrusive mass not far beneath or else mark the spot whence much material was poured out on the old surface above.

---

[1] 15th an. rep't of the N. Y. state geol. 1895. p. 562-66. When this report was written these dikes had not been differentiated from the similar, post-Utica dikes along Lake Champlain, and they are therefore spoken of as bostonites.

The wider distribution of these dikes is of interest. The syenite dikes do not range far to the west and south of Rand hill, and so far as present knowledge goes must be counted by tens in the Adirondack region as a whole. But the diabase dikes range farther to the west and far to the south, and there are hundreds of them. It is also of interest, taking a still wider view, to note that igneous activity was widespread over the land areas and shallow sea bottoms to the east and west of the Adirondacks during these very ancient times, and that the Adirondack eruptives are very like those which characterized Keweenawan time in the upper lake region, and probably approach them as nearly in age as they do in character.

These dikes vary in width from an inch or two to forty or fifty feet. Their contacts with the inclosing rocks are exceedingly sharp. Joints, due in large part to shrinkage on cooling, are much more numerous than in most of the adjacent rocks, so that the dike rocks weather out into a multitude of sharply angular, small blocks.

The syenite dikes are usually of some shade of red, ranging toward and passing into a brownish black in some instances. They mostly show rather large, porphyritic feldspars and sometimes black mica as well. The narrow dikes and the margins of the larger ones consist of very fine grained, flinty rock. Their general composition is of magnetite or specular hematite, hornblende, biotite, microperthitic feldspar and quartz, but they vary greatly in acidity and hence in the relative proportions in which these minerals are present. Some of these dikes have been described in considerable detail elsewhere, and those more recently discovered add little that is new.[1]

The diabases are without exception black in color, weathering to yellowish brown along the joint planes, so that the small weathered blocks show simply this color. They vary in grain with size, but all are very fine grained. Nearly all show porphyritic feldspars which in a few dikes are notably large and may reach a length of an inch, but which are usually minute. These dikes have been described in considerable detail by Kemp.[1] They vary greatly in structure and mineral content. Practically all are porphyritic, but in the center of the larger dikes the porphyritic structure disappears, and the rock becomes a true diabase; otherwise it is more properly a diabase-porphyry. Olivine is almost always present.

---

[1] Cushing, H. P. Bul. geol. soc. Amer. 9:239-56.

These rocks have almost identically the composition of the hyperite-gabbros, yet no garnet, so abundant in the gabbro, has developed. On the other hand, biotite rims around magnetite, specially at magnetite-feldspar contacts, are a conspicuous feature in the diabase, and occur also in the gabbro. The writer has found no biotite in his freshest diabase dikes, and in those in which it occurs it seems always to be surrounded by more or less altered parts of what may be otherwise quite fresh rocks. Hence a disposition to regard it as secondary instead of primary and also to regard it as produced in a more superficial zone than that in which the garnet develops.

The only rocks with which these diabases are likely to be confused by anyone are some of the narrower dikes of hyperite-gabbro. From any of these they may be easily distinguished by their finer grain, greater variation in grain from center to margin, more flinty character and more excessive jointing.

In only one case has it been possible to make a relative age determination between these two sets of dikes. At the summit of Rand hill, one fourth of a mile east of the house of L. Sanger and on the east side of a knoll of gabbro, a 15 inch dike of the syenite-porphyry, bearing n 65° e, is cut by a dike of diabase of the same width bearing east and west. In this case the diabase is indisputably the younger. While this does not make it safe to say that all diabase is younger than all the syenite, it at least points in that direction.

Paleozoic rocks

Potsdam sandstone. Rocks classed as of Potsdam age are at the surface over the larger part of the Mooers sheet. The rock as a whole is of very uniform character, mostly a coarse grit, white or buff in color, lying in quite massive beds which in places weather into flags. Much of the rock is cross-bedded, and the surfaces of many layers are ripple-marked. More or less pebbly layers prevail throughout, though most notably at the base.

---

[1] Kemp, J. F. Bul. 107 U. S. geol. sur. p. 24–29.

The bulk of the formation consists of pretty pure quartz sand. There is considerable variation in thoroughness of induration among the different layers, but the great mass of the rock is not very porous, the interspaces between the quartz grains being very thoroughly filled with secondary silica. Hence but few of the layers are water-bearing.

The thickness of the formation is unknown. The beds are nearly horizontal, the prevailing dip being to the north and seldom reaching 5°, while in the majority of cases it is so slight as to prevent accurate measurement. Dips changing from northeast to northwest indicate the presence of extremely gentle folds. The homogeneous character of the rock makes it impossible to follow individual beds for any distance and also prevents the detection of the faults which are assuredly present. The thickness is unquestionably great, but its determination must await the evidence of the drill, and the recent boring at Morrisonville, the only deep well ever put down in Clinton county, has passed only part way through the formation. The record will appear on a later page, but a thickness of 800 feet of Potsdam has been passed through with no indication of approach to the base of the formation, so that the entire thickness may be double that amount.

The basal beds of the formation differ in character from the main mass, much of the rock becoming coarse and pebbly and some very coarse conglomerates occurring. Red is the prevailing color for the finer grained basal beds, the more strongly colored owing it to secondary deposition of iron oxid (hematite). The basal beds are by no means as purely quartzose as the main mass of the formation, feldspar (mostly red orthoclase) being present in large quantity and in places much magnetite in addition. This part of the rock is more properly an arkose than a sandstone. As these rocks were formed from the ruins of the pre-Cambrian rocks, their composition indicates much only partially decomposed material on the old land surface, and some of the very coarse conglomerates exhibit very coarse material of this kind, only slightly water-worn, as if protected in an old hollow of the surface.

There is much conglomerate in the basal Potsdam of the Mooers sheet but by no means so coarse, or so extensive, as in many other places. But the basal red beds are more widely exposed than in any other part of the Adirondack region. On the north and west of Rand hill there is much thin-bedded, deep red rock which disintegrates easily, and is interbedded with harder and firmer bands of massive red sandstone. These rocks give rise to a deep red soil by their rapid breaking down. The harder beds furnish an excellent building stone, not so flinty and of a deeper red color than the well known stone from Potsdam. These beds seem to mark the extreme base of the formation in this vicinity. They are so extensive and so different from the usual coarse base of the Potsdam that there has been some question in the writer's mind as to whether they properly belong with it, but, aside from their somewhat different lithologic character, no evidence for or against this view has been forthcoming.

On the west side of Rand hill, surrounded by pre-Cambrian rocks on three sides and with their extent to the southwest hidden by the heavy moraine covering in that direction, are two outliers of these red beds, which gave the writer the idea, in his earlier and more hurried survey, that the Rand hill pre-Cambrian rocks were nearly or quite surrounded by the Potsdam. But diligent search in the woods of western Beekmantown resulted in the discovery of three small exposures of gneiss, sufficiently separated to show clearly the absence of the Potsdam. These outliers are at the same elevation as the corresponding beds farther north, no sign of faulting was discovered, and they are believed to occupy old depressions in the pre-Cambrian surface, as Kemp believes similar outliers in Essex county[1] to do.

---

[1] Kemp, J. F. Bul. geol. soc. Amer.

In the southeastern corner of the sheet, on the unnamed hill in extreme northeast Dannemora, the Potsdam sandstone is found at the greatest altitude yet noted for that formation in the Adirondack region. This hill was erroneously mapped as gneiss in the report on Clinton county in the *15th annual report of the New York state geologist.* As it is difficult of access, and time could not be taken to visit it, the topography, the altitude, and the statements of guides were taken as the basis of the mapping. But it seems unsafe to infer anything in Adirondack geology. The ground must be gone over foot by foot.

The hill breaks off in a cliff on the west side which looks like a fault scarp. On the north and east at 1600 feet is a broad shelf of bare, nearly horizontal sandstone, which is covered with blueberries and reproduces, on a small scale, the conditions on the Flat rocks in Altona. Rock was found exposed on the hill up to 1700 feet. The top is covered with morainic material but how deeply is uncertain; the Potsdam certainly runs up to something over 1700 feet however. A section of at least 200 feet in thickness is comprised in the hillside. The occurrence of the rock at this elevation is strongly suggestive of its former much greater extent in the region.

Passage beds. Between the Potsdam and the overlying limestones is a zone, some 50 feet in thickness, of rapidly alternating layers of pure white sandstone with all the lithologic characters of the Potsdam, and gray, sandy, dolomitic limestone precisely like the Calciferous above. These beds have been usually classed with the Potsdam. The only exposures of these beds within the limits of the sheet are in the northern part of Mooers township. The geologic map of Canada shows Calciferous coming down to the boundary at this point, but on the New York side of the line there is no Calciferous exposed unless these passage beds are to be counted such.

Calciferous (Beekmantown) limestone.[1] Though rocks of this age are the surface rocks over a considerable tract, they are effectively concealed by heavy drift except at West Chazy, where a thickness of 10 feet of massive, blue-gray dolomite is exposed in the river and a higher layer at the surface in the town. South of West Chazy and east of Rand hill there is not a single exposure of rock within the limits of the map, though plentiful outcrops occur in Beekmantown, just beyond those limits. Some uncertainty therefore prevails as to just what is underneath. It is the writer's opinion that the Calciferous extends all the way to the edge of the Rand hill, being there faulted down against the pre-Cambrian. This opinion is based on the fact that to the south, in Plattsburg, the Calciferous runs as far west as what is taken to be the prolongation of this fault line. But it is by no means impossible that another fault is concealed in this interval, in which case Potsdam would lie between the Calciferous and the pre-Cambrian. On account of this uncertainty the concealed interval is colored as Pleistocene on the map, such coloration being used only where the Pleistocene deposits are sufficiently extensive to render the areal mapping of the older rocks at all doubtful.

---

[1] Clark & Schuchert. Science. 10:874–78. The term, Beekmantown, is much more suitable than the old name and should supersede it. The type localities are just outside the limits of the sheet.

The Calciferous formation is a quite thick one in the Champlain valley, Brainard and Seeley having shown a thickness of 1800 feet in western Vermont. No complete section has been found in New York, but the different parts of the formation show much the same thickness as in Vermont, and the total thickness can not fall greatly short of the amount found there. The meager exposures at West Chazy do not suffice for the determination of the precise horizon in the formation. They lie close to a fault line, dip 5° to the east instead of in the usual northerly direction and may represent a small dislocated block produced by the faulting.

Chazy limestone. Only the extreme lower beds of this formation are shown within the map limits, occupying a narrow zone between two great faults, between which the Chazy is thrown down. The dip is away from the westerly and toward the easterly fault. The extreme base is not shown, but the lowest layer appearing is a light colored, calcareous sandstone which seems very similar to the sandstone described by Brainard and Seeley as forming the base of the Chazy on Valcour island, and elsewhere along the lake.[1] The rock is peculiar and precisely like layers which are found in the Potsdam-Calciferous passage beds. Glittering cleavage faces of calcite, mottled with quartz grains, appear on broken surfaces. The quartz grains are set in a mosaic of minute dolomite crystals, while here and there later calcite has been deposited as a network around the quartz grains in crystals up to an inch in length, replacing the dolomite in those portions.

Above this layer appears some 20 feet of blue, crystalline limestone, following which are beds of gray limestone, spotted with yellow and full of fossils, to a thickness of 30 feet. The most extensive exposures are along the low ridge east of the big bend in Tracy brook. These upper beds are the same as those which form the base of Brainard and Seeley's section near Chazy village, but the basal 20 feet is below anything there seen.[2]

This lower Chazy limestone is, with the exception of the Pleistocene deposits, the youngest rock now found in the Mooers sheet area. There can be no question however that the remainder of the Chazy (750 feet thick), the Black river and Trenton limestones and the Utica slate (of undetermined thickness but at least 1000 feet) were originally deposited over the entire area. Then followed emergence and the long continued existence as a land region.

The Morrisonville well. Within the past two years drilling for oil has been in progress at Morrisonville, in Plattsburg township. The locality is 4 miles south of the map limits and nearly 3 miles west of its eastern edge. As soon as it was learned that drilling was in progress, a request was sent that a record and samples be kept. An unfortunate fire, however, destroyed the engine house in which the record was placed. A few samples had been kept elsewhere, and what follows is based on these together with the coinciding statements of the owners and the driller, these giving only rough determinations, which however affect the value of the record less than would be the case were the rocks in the well less homogenous.

---

[1] Bul. geol. soc. Amer. 1891. 2:295.

[2] American geologist. Nov. 1888. 2:324.

The drill at present rests at 1350 feet, and no work has been done for some months, though it may again be resumed. Some 20 feet of glacial deposit was passed through, and dolomite of Calciferous age was struck just below the river level, near which the well is located. Some 500 feet of Calciferous are shown in the well, and between 500 and 600 feet, the alternating layers of dolomite and sandstone marking the passage beds to the Potsdam, were met. The thickness of these could not be learned. The remainder of the well is in the Potsdam, mostly of hard, quartzose, white sandstone except for a considerable thickness of red beds, encountered between 800 and 900 feet. At the time of the writer's visit the well, at 1250 feet, was in resistant, white Potsdam, little other than quartz showing in the sample. F. E. Pierce of Morrisonville, one of the owners, writes me that the last 100 feet has been in precisely similar rock. This means that from 750 to 800 feet of Potsdam has been passed through in the well with no sign, as yet, of the arkose beds which always come in as the base of the formation is approached. The record is as follows:

	FEET
Pleistocene	20
Calciferous	500±2
Passage beds	50 (?)
Potsdam	775±2

In all this great thickness of Potsdam sandstone only one stratum was markedly water-bearing. A trifling amount of oil was also found in one of the beds.

Structural features

Foliation. This structure is confined to the pre-Cambrian rocks and was produced in them by deformation at a time when the present surface rocks were so deeply buried as to be beneath the level at which open fractures can exist. It is most prominent in the gneisses of the Dannemora formation, less well marked and locally lacking in the gabbroic intrusions, and wholly absent in the later dikes.

The direction of strike of the foliation planes is quite uniform throughout the area of the sheet and beyond, being in general to the northeast. The more common direction is n 35° e, though the readings range between the extremes of n 10° e and n 50° e; variations of more than 10° from the usual direction are, however, uncommon. The prevailing direction of dip is to the northwest, this being uniformly true at the east and the west, while in the center of the sheet these are replaced by southeast dips. In general the dip is not high, seldom exceeding 45°, and usually flatter than that, often only 10° to 15°. The few good exposures show that the dip sometimes becomes momentarily high, quickly flattening again to the usual amount. The direction and dip of the foliation are common to gneiss and gabbro alike and must have a common origin. The foliation has a general parallelism to the longer axis of the intrusive mass of gabbro, yet continues unchanged so far to the south of that, with no apparent tendency to curve around its southern end, as to cause hesitancy in assuming that the compressive effect of the intrusion has been mainly instrumental in the production of the foliation. Farther, though observations on the foliation of the later hyperite-gabbro are somewhat unsatisfactory, they point to its parallelism with that in the other rocks and indicate that, in so far at least, the cause of the foliation is in no way to be ascribed to the larger intrusion. It is of course a possibility that the Rand hill gabbro is merely the bared, upper part of a great intrusive mass, much more widely extended beneath than the surface exposures give any indication of. The character of the rock, so like peripheral portions of the great anorthosite masses to the south, may be as well explained by this supposition as by the idea that it is a small, outlying intrusion, its character due to differentiation prior to its movement to its present position. The gently folded character of the foliation planes may give weight to the idea of a widely extended igneous mass not far beneath. In general it may be said, therefore, that the evidence is far from decisive as to the gabbro intrusion being the cause of the foliation, nor does the latter show parallelism to the edge of the main intrusive masses of the Adirondacks. It can be equally well, perhaps better, explained as due to a force acting from the southeast, or from the northwest, presumably the former, and acting at several different times. On the latter assumption the decreasing perfection of the foliation in the successively younger rocks would be explained.

Nothing that could be definitely recognized as bedding has been observed in the Dannemora gneiss. Granite injections parallel to the foliation planes often give a bedding effect, as do also certain bands of hornblende gneiss, which cut across the foliation and are held to represent ancient, diabase dikes. With these exceptions the different varieties of gneiss fade into one another instead of being sharply marked off.

Faults. The region of which the Mooers sheet is a part is an excessively faulted one, not only great breaks but many minor ones occurring. Their detection is a matter of great difficulty over much of the territory, owing to widespread drift covering and specially to the uniformity in lithologic character of the pre-Cambrian rocks and of the Potsdam sandstone.

The greatest break known in the vicinity is that which has been called the Tracy brook fault.[1] This is easily traced, running in a northeasterly direction, across the whole of Chazy township with the Potsdam sandstone on one side and the various members of the Chazy limestone on the other, the entire Calciferous being faulted out. Its course is easily traced from the point where it enters the sheet, north of West Chazy, to the point where the brook leaves thé fault line. Beyond, its course is conjectural. If produced, it would touch the northeast extremity of Rand hill, along whose eastern edge there is unquestionably a fault of great magnitude, the cliff being a fault scarp whose present relief is due to the more resistant character of the rock on the west, possibly aided by recent movement. The way in which the Potsdam contact on the north climbs the hill, rising from 800 feet to 1400 feet within a distance of 3 miles, is strongly suggestive of recent faulting and tilting, since there is no topographic break between the two rocks, yet one is far less resistant than the other.

---

[1] 15th an. rep't N. Y. state geologist. 1895. p. 570.

The only difficulty in the way of considering this the prolongation of the Tracy brook fault is the sharp change in direction from southwest to south at the point of Rand hill. It is quite possible that this point marks the junction of the Tracy brook fault with a north and south fault, of whose existence the topography on that line north of Rand hill gives some evidence. At the best, however, this is not a fault of great throw, while that on the east edge of Rand hill is directly comparable in magnitude to the Tracy brook. As it can be traced to the south beyond the limits of the sheet and clearly connects with the Tracy brook fault, it gives great length and importance to this. If the writer be correct in the belief that the Calciferous comes clear to the edge of Rand hill, the entire Potsdam being faulted out, then the throw of the fault there is as great, or greater than at Chazy village, where it is about 2000 feet.

Another considerable fault occurs between the Calciferous at West Chazy and the Chazy limestone to the northward, the latter dipping directly toward the fault. The throw of this fault can not be determined owing to the uncertainty as to the precise horizon in the Calciferous of the West Chazy exposures.

Other faults or probable faults are (*a*) one in the extreme north that limits the passage beds on the west, which have a low northwesterly dip, yet suddenly disappear and are replaced by Potsdam to the westward; (*b*) a fault of unknown throw in the Potsdam at Jericho, with the red, basal beds on the east side and a coarse, glassy sandstone on the west, the one horizontal and the other with a 6° dip to the west; and (*c*) a more doubtful fault across Rand hill, separating the Potsdam and Dannemora gneiss on the west from the gabbro on the east.

In addition to these greater faults there are a multitude of minor breaks in the pre-Cambrian rocks at least, best shown by the aid of the later dikes. These are frequently found faulted a few inches or feet, little enough to make the identity of the dike unmistakable, and frequently enough to emphasize the great number of these small slips that must exist. The slickensided character of many of the joint planes is evidence of slipping along them.

The faults run in all kinds of directions. The greatest breaks have a general north and south trend, though they may depart from this as much as 45°. Instead of being persistent in direction, they curve largely. The downthrow is always on the east side, with the result that progressively younger rocks appear as Lake Champlain is approached. The general rude parallelism of these faults cuts up the region into a series of long slices. These are cross-faulted, sometimes repeatedly as in the case of the block on the east of the Tracy brook fault, but usually much less frequently. The cross faults have a general east and west trend, but depart widely from that, and may or may not be normal to the main faults. No case has been met with where one crosses a main fault. They are necessarily of less magnitude though often with throws of many hundred feet.

The majority of the faults of the region are certainly normal (gravity) faults, and this is likely the case with all. The rocks lie in exceedingly gentle folds, and thrust faults, if present, must hade to the west, as all the great faults downthrow to the east. Across the lake the rocks are more sharply folded, and there thrust faults occur, but with a hade to the east.

Joints. All the rocks of the region are cut by joints and generally by several sets. Unfortunately observations on them do not suffice definitely to determine their character; observations on the strike are plentiful, but the dips can seldom be made out.

The most common direction of joints is a nearly north and south one varying between n 20° w and n. In nearly every case in which these are observed joints at right angles can also be made out, from n 70° e to e. In the majority of exposures these seem to represent the master joints. But northeast and northwest joints are nearly as common and in many exposures seem more prominent than the other set. There are evidently two sets of main joints, each consisting of a pair at right angles to each other, and the two sets cutting one another at 45°. It is to be noted that while the north and east joints of the first pair are at 45° to the strike of the foliation planes, the northeast joints of the second set are parallel to and the northwest at right angles to these planes. Whereas therefore this latter pair of joints might have been produced by forces acting in the same direction as those which caused the foliation, the first pair could not have been so produced. It should also be noted that the first pair are more prominent in the Paleozoic rocks than are the second, while they are about equally developed in the pre-Cambrian rocks.

Many joints have been noted which can not be brought into either of these sets, but they are of much less importance and their significance is not clear. The numerous tension joints of the later dikes, which are manifestly due to contraction on cooling, are not here had in mind.

Wherever observations on the dip of the n 20° w and n 70° e pair of joints have been possible, they have been found to be vertical or very steeply inclined. But the northeast joints, those striking with the foliation planes, have been several times noted with dips of from 45° to 60° to both the southeast and the northwest, indicating that they are compression joints, and that the pressure came from the same direction as the earlier pressure which produced the foliation. In general these joint planes do not coincide with the foliation planes but are somewhat more steeply inclined. Observations on the dip of the northwest joints are practically lacking, though they seem to belong with the previous set and to have been produced at the same time. The vertical north and east joints are perhaps tension joints.

As the compression joints are lacking in the Paleozoic rocks, they must antedate the Potsdam. The prevailing east and west trend of the diabase and syenite dikes argues for an existing set of fissures with that trend at that time. The Palezoic rocks are also jointed, mainly by the north and east set. At least three, and probably several periods of joint formation are thus indicated.

Many of the joints are slickensided, indicating that slight slips have taken place along them, and not improbably a considerable part of the readjustments of the region have been effected in this way, since many slight slips may involve as great an amount of shift as that concentrated along a single great fault.

Pleistocene deposits

The retreating and disappearing ice sheet of the glacial period dropped its burden of transported rock material very unequally; much at points which mark pauses in the retreat; far less over places away from which the retreat was rapid; much also in the depressions of the preglacial surface, filling them often to the brim. In the district immediately under consideration glacial deposit, morainic and of till, is widespread but of very unequal thickness and with much bare rock showing. In places are very considerable morainic accumulations. The old preglacial valleys cut in the high plain level are refilled to that level, while the old hill tops and divides are but scantly covered.

Moraines. Much the most considerable line of morainic deposit is that banked up against the southeast face of Rand hill, climbing up and overtopping it to the south and swinging to the west up the north side of the Saranac valley, deeply covering all rock over a great area, and not improbably hiding the preglacial Saranac valley as well. The moraine is quite sandy, as is true of all moraines hereabouts, in consequence of the large content of material derived from the Potsdam sandstone. It is also very stony, and again material of Potsdam source is much the most conspicuous element. Locally the surface is exceedingly stony, Potsdam boulders by the hundred lying about together with crystalline rocks from Rand hill and rare Calciferous and Canadian pre-Cambrian blocks. This is undoubtedly the moraine mentioned by Baldwin in his paper on the Pleistocene of the Champlain valley.[1] This moraine, which covers all the south face of Rand hill and the low hills westward, as well as the south slopes of Dannemora mountain, so that all rock is hid and the pre-Cambrian–Potsdam contact efficiently concealed, would seem an unmistakable terminal moraine.

---

[1] American geologist. 1894. 13:394.

The east and west road in Beekmantown just at the south limits of the map passes over a series of ridges at progressively higher and higher levels, which somewhat resemble beaches in shape but do not seem to be such, as they consist in large part of rather coarse and not well water-worn material. It is probably to these that Prof. G. F. Wright alludes in a short paper, and these that he calls lateral moraines.[1] The writer has not given them sufficiently critical study to speak positively of their nature, but is disposed to agree that they are due to lateral streams along the edge of an ice tongue which lingered in the Champlain valley after the ice had disappeared from the hills. Deposits of apparently similar origin run north along much of Rand hill between the 600 and 800 foot levels. A single knob at the 700 foot level appears like an elongated drumlin, as suggested by Prof. Wright. Its surface is profusely covered with boulders and it is apparently of till, no exposures occurring. A little over a mile north of this drumloid hill is another knob of till or moraine at precisely the same level, and a mile and a half farther north, in Altona, is yet another of still more elongated shape. A satisfactory explanation of these three outlying knobs with identical summit levels has not presented itself.

In the northern half of Mooers the drift is very heavy and is morainic, though no bulky and conspicuous terminal moraine appears, and in general the moraine covering over the till is not thick, so far as can be judged by the few stream sections. The irregular, hummocky topography and numerous marshes are characteristically morainic. Yet occasional rock outcrops show in this belt, and the streams not infrequently show ledges in their beds. There is no indication that the ice made more than a very brief pause along this line.

Another similar east and west belt, with a breadth of some 2 miles, crosses southern Altona. Heavy boulder trains, mainly of Potsdam sandstone, are frequent on the surface. Like the previous belt, this does not mark a protracted pause in the general ice retreat.

---

[1] American geologist. 1898. 22:333-34.

Glacial striae. Over a large part of the area of the sheet the striations on the rocks show that the ice which produced them was moving in a southerly direction. This is not the usual direction in the Adirondack region, and these markings were evidently produced by ice whose direction of movement was controlled by the meridional depression of the Champlain valley. On Rand hill the direction was midway between this and the usual southwesterly direction which prevails throughout the northern Adirondacks, the readings varying between s 5° w and s 30° w.

Water levels. Signs of the action of standing water are numerous in the region, but the writer has been unable to give them the attention they deserve and can speak of them only in preliminary fashion. Fragmentary beaches and terraces are found at the 360 and 440 foot levels, less well marked at 280 feet and somewhat doubtfully at 540 feet. The two best defined levels are marked by fragmentary beach ridges, behind which are often long narrow marshy strips, and by sand delta levels in the Little Chazy river. North of West Chazy what resemble cliffs and wave-cut terraces appear at these levels, but some hesitation is felt in ascribing this origin to them, since they are found at other levels also, and the rocks are so resistant that the length of time required for the work would seem out of all proportion to the length of time during which the water stood at these levels, as indicated by the strength of the beaches and delta terraces. Wave action was probably effective in sweeping away all fine material from the benches, but that they were cut by the waves is not thought probable. The cliffs may be fault scarps.

Baldwin reports marine shells from Plattsburg township at 346 feet, and there can be no question that the water level at 440 feet represents marine submergence to that depth. But signs of wave action between 500 and 540 feet were noted in several places, and it should be added that one of the great sand terrace levels in the Saranac valley has the same altitude. On the turnpike at West Beekmantown and southward is much sand at 520 to 540 feet with strong resemblance to a beach. There is a sand terrace level along the river west of West Chazy at the same elevation. In eastern Altona at the same level rather gravelly ridges are found at two or three points which resemble beaches. On the road west from Sciota to Altona village, similar ridges appear at 480, 540 and 580 feet, built up on the sandstone ledges of the Flat rocks, all beach-shaped but with much coarse and not well rounded material. At 500 feet is an interesting little gravel bar, like a spit, now cut through by a small stream. These Altona ridges have considerable resemblance to those in Beekmantown already described and may perhaps also be referable to lateral stream action along a Champlain valley ice tongue, but their persistence at about the same level, and the correspondence of this with the delta level in the Saranac valley, seem to indicate strongly static water action. It need not necessarily mark a marine level, as there are fresh-water levels above the marine shore lines in the region, but, on the other hand, the hight reached by the marine levels on Mt Royal at Montreal would seem to imply a marine level along Lake Champlain at least as high as this.

These shore lines in the Champlain valley rise in level when followed northward, showing that they have been tipped since they were formed, but, till they shall have been more carefully followed and identified along the full length of the valley, uncertainty must prevail in respect to the amount of canting.

The Flat rocks

The Flat rock district in Altona is a most impressive region The naked ledges of horizontal sandstone, rising slowly in a series of gigantic steps with wide tread and low rise, are extremely striking. That the ice could have melted away from the region so rapidly as to leave no deposit here is not to be thought of. Deposit evidently was left and has since been removed. Some four years ago G. K. Gilbert, who had recently returned from a short visit to the region, suggested in conversation that here was the route of a spillway. As the ice retreated away from the northern foothills of the Adirondack region, the waters of the glacial lake Iroquois, which occupied the Ontario basin and had its outlet at Rome into the Mohawk valley, because the St Lawrence outlet was still blocked by the ice, would have commenced to discharge around on the north along the edge of the ice as soon as it had sufficiently retreated to uncover lower ground than that at Rome. By a spillway such an outlet is meant. As the ice farther retreated down the slope, the stream would fall to successively lower levels, bringing down the level of Lake Iroquois correspondingly. Such a current as this would have been would furnish an adequate explanation of the naked rock surface of the Flat rocks. The writer's observations have not been sufficiently extensive along the north side of the Adirondacks to enable him either to affirm or to deny the correctness of this view, and, as the results of Mr Gilbert's observations have not been published, it is not known on what data the identification of this spillway rests. But such results would naturally have followed the change in outflow of Lake Iroquois from the Mohawk to the St Lawrence valley, and spillways would likely have existed at several levels as the waters fell. Various lake levels should also have existed for at least a brief time along the northern Adirondack slopes, and may well have left discoverable traces, which should have definite connection with such spillways as may exist. The region is a difficult one, but a great opportunity awaits the individual who can take the time to cover the region thoroughly, unhampered by other and more pressing work. The new maps will be a great aid when completed.

The larger part of the bared surface in the Flat rock district lies between 600 and 800 feet elevation. Over large areas the surface is absolutely naked except for an occasional large boulder. This altitude is so much below the level of the Iroquois beach, if extended to this point, that, if it be the path of a spillway, it should be from a water level considerably lower than the main Iroquois plane, and it would seem as if marks of standing water at this lower level should be found when search is made.

Just below the eastern edge of the bared rock area in eastern Altona is an exceedingly interesting ridge of coarse cobbles which